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ПІДВИЩЕННЯ ЕФЕКТИВНОСТІ СТВОРЕННЯ ЗАХИСНОГО ОДЯГУ

Анотація.

Метою статті є розвиток методів проектування захисного одягу для підвищення його ефективності за показниками захисту, надійності, економічності та безпеки використання. Запропоновані авторами методи зі створення захисних засобів скеровано на удосконалення методів проектування і конструювання, подолання виявлених вад виробу і підвищення комфортності у використанні. Запропоновано виготовляти захисний одяг з композиційних матеріалів, що дає можливість розширити захисні функцій і підвищити тривалість використання. Розроблено дво і тришарові матеріали, в яких як основу використано неткані матеріали з поліефіру або поліпропілену, що забезпечило потрібний рівень адгезії і повітропроникності. Основу вкрито з одного або обох боків композицією полівінілхлориду. Під час конструкторської розробки захисного одягу використано основні положення методу трансформації. Захисний одяг призначено для роботи в умовах підвищених температур, вологості і швидкості переміщення повітря та температурних коливань. Головні вимоги до захисного одягу – створення відповідної конструкції, яка забезпечує скочування рідких речовин з поверхні одягу, комфортний мікроклімат у підодягову простору, надійну герметизацію від пилу та функціональні кишені. Захисний одяг запобігає виникненню мікротравм шкірних покривів тіла працівника, впливу вугільного та породного пилу, олій, водоолійних емульсій, має захисні властивості від α- і β-випромінювань. На підставі узагальнення практичного досвіду сформовано асортиментний ряд захисного одягу багаторазового використання: куртки, напівкомбінезони, штани, наколінники, налокітники. У комплекті разом зі захисним одягом використовують фільтрувальний респіратор, каску, рукавички та захисне взуття (чоботи).

Ключові слова: проектування захисного одягу, композиційні матеріали, метод трансформації.

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GROWTH IN EFFECTIVENESS OF PROTECTIVE CLOTHING

Abstract.

The purpose of the article is the development of the methods of designing the protective clothing for the workers in order to increase their efficiency in terms of protection, reliability, cost-effectiveness, and safety of use. The methods for the creation of protective equipment, proposed by the authors, are aimed at improving the design and construction methods, overcoming of the defects found and improving the comfort of use. It is suggested to make protective clothing from the composite materials, which gives the opportunity to extend the protective functions and increase the duration of use. Two and three-layer materials were developed,

composed of non-woven fabrics made of polyester or polypropylene, which provided the required level of adhesion and air permeability. The base is coated on one or both sides with a polyvinyl chloride composition. During the development of the design of the protective clothing the basic provisions of the transformation method were used. Protective clothing is designed to work in the conditions of high temperatures, humidity, speed of air movement and temperature fluctuations. The main requirement to the protective clothing is the creation of the appropriate design that provides the slide down of the liquid substances from the surface of clothing, comfortable microclimate in under-the-clothing area, reliable hermetization from dust and functional pockets.Protective clothing prevents the microtraumas of the skin of the worker's body, the impact of coal and rock dust, oils, water-in-oil emulsions, has protective properties against α- and β-radiation. On the basis of generalization of the practical experience, the following assortment range of protective clothing for multiple uses has been formed: jackets, bib overalls, pants, knee-pads, elbow-pads. Filtering respirator, helmet, gloves and protective shoes (boots) are use in one set with the protective clothing.
***Keywords**: designing of the protective clothing, three-layer materials, transformation method.*

1. Statement of the problem

Creation of safe working conditions and realization of the best European and world practices of industrial safety in Ukraine is impossible without the design, manufacture and introduction of qualitatively new types of personal protective equipment of the workers. Such kind of approach is the most effective taking into account in the conditions of transition economy and technical conditions of the most of production assets in Ukraine. Ergonomic imperfection and the lack of reliable protection of the workers during the professional-production activities leads to physical overloads, complications and limitations of characteristic movements, imbalance of the thermal balance due to the inadequacy of structural and technological solutions of the products to the working conditions, and as a consequence, leads to the reduced efficiency and increase of the risk of injury. Therefore, the scientific and technical task for the development of scientific principles of designing the protective clothing for the workers of domestic enterprises that contributes to reducing of occupational injuries, the number of occupational diseases and the improvement of labor safety, does not lose its relevance.

Personal protective equipment refers to the means intended to eliminate or significantly minimize the complex impact of all available hazardous and harmful production factors (HHPF) on the worker in the workplace. Depending on the purpose, personal protective equipment are divided into 12 classes in Ukraine, each of which consists of several dozens of kinds and types. In the absence of the universal unified classification, each type of PPE is classified according to the number of features: by protective properties; by appointment; by design execution; by model range, by the term of use.

As to the personal protective equipment, in order to perform their functions, they must, according to the purpose and degree of the protection, be clearly in line with the nature and level of the HHPF, and at the same time be acceptable from the physiological and ergonomic point of view, that is to provide the physical and technological compatibility of the individual PPE in the set of clothing, as well as with the object of protection, namely the worker. It is necessary to consider the set of personal protective equipment as a whole, since contamination of any part of the body can cause the affection of the worker. Such approach can be realized by selecting the appropriate materials, scientifically grounded design and technological development of PPE and their sets. Sets of personal protective equipment need to be considered as the final link in the chain: working conditions – HHPF – priority of the affection of human organs and tissues – set of personal protective equipment.

The purpose of the article is the development of the methods of designing the protective clothing for the workers in order to increase their efficiency in terms of protection, reliability, cost-effectiveness, and safety of use.

The elements of system analysis and mathematical modeling as a means of solving the tasks are the basis of the research. During the development of the design of the personal protective equipment the basic provisions of the transformation method were used. Live experiments are used as a means of checking the adequacy of the proposed mathematical models and carried out using the modern measuring instruments in accordance with the methods given in the standards for the relevant personal protective equipment.

The practical significance of the obtained results is that theoretical generalizations and results of calculations have been used as a methodological basis for developing the approaches to designing the new high-performance types of personal protective equipment, the application of which will make it possible to increase the safety and productivity of labor and to reduce injuries and occupational diseases.

2. Main material

Nowadays in Ukraine the number of accidents and injuries, caused by them, is decreasing gradually, but at the same time there is negative trend – the growth of occupational diseases due to the further worsening of working conditions, aging and wearing of machines, mechanisms, buildings, facilities, untimely repairs and maintenance. In the industry, the number of the workplaces that do not comply with sanitary and hygienic standards and regulations is increasing. On the average (20 ... 25) % of the workers are constantly under the influence of the harmful working conditions. The share of the workers who work in conditions that do not meet sanitary and hygienic norms and safety standards is constantly increasing (from 17.1 % in 1997 to 30 % in 2015). Under such conditions, almost every third employee works today, which are almost three million peoples.

The manufacture of PPE increases in Ukraine every year, the use of which helps to reduce the level of injuries and occupational diseases. The effectiveness of PPE application depends on the correctness of their choice and reliability during the

operation and storage. The list of personal protective equipment is established by relevant norms or departmental documents, which are formed on a priori considerations, outdated experience and documentation, which does not provide for the use of mathematical justification. During the works in harmful conditions workers are provided with the appropriate personal protective equipment on the free of charge basis. Protective clothing are given to the workers in accordance with the established rules and terms of wear, regardless of the form of ownership and industry. As of 2017, 82 normative legal acts on labor protection are in force, which define the norms of the elements of system analysis and mathematical modeling as a means of solving the tasks are the basis of the research. During the development of the design of the Protective clothing the basic provisions of the transformation method were used. Live experiments are used as a means of checking the adequacy of the proposed mathematical models and carried out using the modern measuring instruments in accordance with the methods given in the standards for the relevant personal protective equipment.

However, the lack of a unified methodological approach to ergonomics, protection and durability indicators, based on clear mathematical models and methods, creates significant difficulties for the PPE developer and the user. The uncertainty of the requirements results in a long process of certification and the introduction of new types of personal protective equipment in production.

The methods for the creation of protective equipment, proposed by the authors, are aimed at improving the design and construction methods, overcoming of the defects found and improving the comfort of use. In the context of market relations, taking into account inflation processes, uncertainty of information and goals, it is necessary to find the new methodological approaches that will provide effective methods of design, production and operation of personal protective equipment.

Personal protective equipment is a structural product, the elements of which differ in physical, mechanical, temperature, hygienic, and electrical parameters, which directly affects the level of their efficiency, quality, reliability, and cost effectiveness. When designing, developing and manufacturing the PPE, usually it is necessary to provide requirements that are controversial.

It is suggested to make protective clothing from the composite materials, which gives the opportunity to extend the protective functions and increase the duration of use. Two and three-layer materials were developed, composed of non-woven fabrics made of polyester or polypropylene, which provided the required level of adhesion and air permeability. The base is coated on one or both sides with a polyvinyl chloride composition. The materials are impermeable to water, lubricants, acids and alkalis, have a high level of physical and mechanical characteristics (the breaking load is 78.8–93.4 H, resistance to thawing 6.3–8.7 H), low vapor permeability (2.3 mg/(cm^2·hour) and air permeability (17 dm^3/(m^2 ·sec). The surface densities of the materials are 270–370 g/m^2, so the weight of the clothing is within the range of 1.3 ... 2.3 kg depending on the model that is not exceed the limit value of 135 kPa pressure on the vital organs of the human.

Protective clothing is designed to work in the conditions of high temperatures, humidity, speed of air movement and temperature fluctuations. Protective clothing

prevents the microtraumas of the skin of the worker's body, the impact of coal and rock dust, oils, water-in-oil emulsions, has protective properties against α- and β-radiation.

However, such materials have a considerable surface electrical resistance of (10^8…10^{12}) Ohm, which exceeds the permissible levels for mines operating in Ukraine. In order to reduce the electrical resistance to the level of (10^6…10^8) Ohm, the stitching with metallic fibers is used in the connections of the parts of the products.

In unsatisfactory visibility conditions (the light provided by individual lamps does not exceed 1.5 candle-meters) and high level of dusty air, there is a high probability of injury to the workers by mechanical and transport means. In order to improve the safety of the work, it is advisable to wear identification labels from reflective materials such as Pentaline, Nippon, with reflections of not less than four units on the protective clothing.

On the basis of generalization of the practical experience, the following assortment range of protective clothing for multiple uses has been formed: jackets, bib overalls, pants, knee-pads, elbow-pads. Filtering respirator, helmet, gloves and protective shoes (boots) are use in one set with the protective clothing. The main requirement to the protective clothing is the creation of the appropriate design that provides the slide down of the liquid substances from the surface of clothing, comfortable microclimate in under-the-clothing area, reliable hermetization from dust and functional pockets.

The basic designs of the protective clothing, consisting of a jacket and pants, are developed. It is found that the protective clothing on the knees, elbows, shoulders, hips and lower legs wears off very quickly. Depending on the design of the suit, three models were designed. The first model consists of a straight jacket with set-in sleeves and fastens to the right-to-left for five pairs of half-circles, has the ventilation openings in the arm-holes. Sleeves are single-joint, with elbows, upturns or wrist braces, back is without stitches, collar is banded. On the front, the patch pockets are sewed. Depending on the working conditions, the jacket can be made with two pockets – two side or two breast pockets. In order to protect the scapular waist and upper back from the mechanical damage, amortizing pads, which are inserted into the shoulder-pads and a special pocket on the top of the back, are used. Pants have the expanded vees, designed to provide the freedom of movement. Fastener has three buttons – one on the belt, two on the fly front. In order to increase the duration of use of the pants, the knee-pads are sewed from the main or stronger fabric on the front halves, and the reinforcing pads – on the back halves. At the worker's request, the pants can be made with straps, with patch pockets on the right and left halves, and with elongated knee-pads.

The second model of the suit has a jacket without side stitches; a yoke is fully cut with the sleeves without shoulder stitches, and elbow-pads. On the lower halves of the sleeves ventilation openings can be made. Such kind of design of the jacket provides greater air-tightness and is recommended for work on the passage of vertical stems with a large influx of the water. At the bottom of the back of the jacket, a rubber for pulling can be sewed, the collar can be of turn-down or turn-

over type, the sleeves can be with the wrist braces or elbow-pads. The jackets are made with a hood or in a complete set with a hat. The hat has a form of a cap and consists of four let-in pieces on the back-cloth, with double fields. In order to provide the water impenetrability, the pants are designed without stitches, with straps, with inserts made of elastic tape, which fasten in the front half on the half-rings. In front, in the middle stitch, the muff is sewed, pulled by the strap detail fasten on the half-rings. In order to extend the use, at the lower part of the pants, in the area of the step stitches, as well as on the knees, the reinforcement pads are welded.

The possibility of the fast finding of the worker in conditions of limited visibility (dullness, poor lighting, dustiness, etc.) and a beautiful aesthetic perception is provided by horizontally and vertically located signal belts, which are connected with a product by a filamentous method along the bottom of the sleeves, in the knees area, along the line where the yoke is sewed on the back and other parts of protective clothing.

The new models of protective suits stop up to 80 % of dust, 20 % of dust reach the underwear. They reduce the index of dustiness of the skin to 0.02 ... 0.03 g per 100 cm^2. In the complete set (protective suit, underwear and shirt), the dust can be reduced to 0,003 ... 0,005 g per 100 cm^2, which is respectively 7 ... 9 times lower than the initial level.

3. Conclusions

The methods for the creation of protective equipment, proposed by the authors, are aimed at improving the design and construction methods, overcoming of the defects found and improving the comfort of use. It is suggested to make protective clothing from the composite materials, which gives the opportunity to extend the protective functions and increase the duration of use. The practical significance of the obtained results is that theoretical generalizations and results of calculations have been used as a methodological basis for developing the approaches to designing the new high-performance types of PPE, the application of which will make it possible to increase the safety and productivity of miners and to reduce injuries and occupational diseases.

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